IMPROVED MAIN SHAFT SEAL LIFE IN GAS TURBINES USING LASER SURFACE TEXTURING

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Overview

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GOALS:

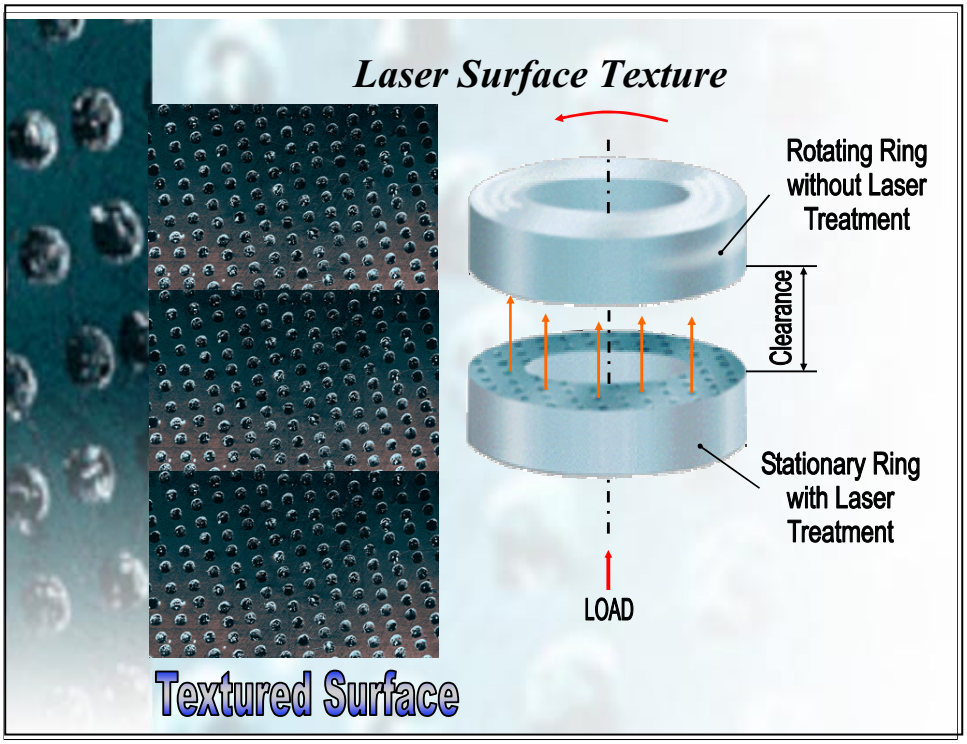
- Develop computer code for hydrodynamic force evaluation
- Develop Laser Surface Texturing (LST) for mechanical seals
- Increase Seal Life & Performance

APPLICATIONS:

- Gas Turbines (aviation & land based)
- Turbomachinery
- Automotive Engine Components
- Mechanical Seals

FUNDING (PARTIAL):

- **B**i-national **I**ndustrial **R**esearch & **D**evelopment Fund (BIRD)
  - » Sponsored by the Israeli government
  - » With participation of foreign company (Stein Seal Co.)


Laser Surface Texture
Rotating Ring without Laser Treatment
Clearance
Stationary Ring with Laser Treatment
LOAD
Textured Surface

Laser Surface Texturing System

- Reliable, non contact method for surface treatment
- Treatment of all types of materials, including metal, graphite, ceramics, composites, etc.
- Environmentally friendly.
- Computerized control of pore parameters allowing optimal shaping of various areas.
- Fast coverage of large areas.

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Seal Schematic with LST applied

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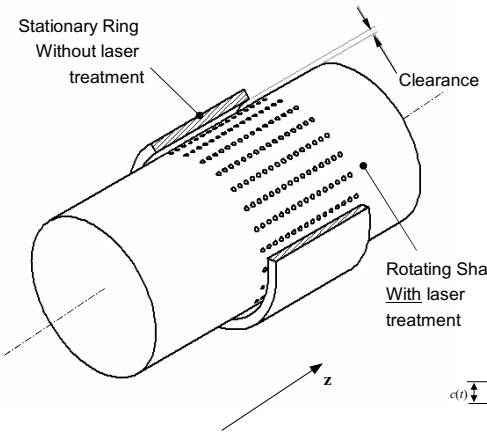
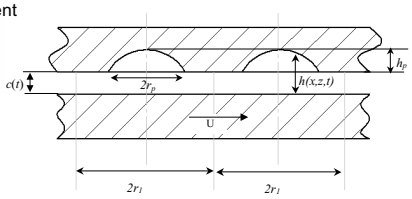


- LST is applied to the shaft (runner).
- Pore pattern is application specific
  - .0039” O pore (100 µm)
  - .000079” depth (2 µ m)
  - Density (spacing pattern)
- 7.100” O carbon circumferential seal chosen.



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Dynamic Rig Tests

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TWO TEST RIGS UTILIZED

1. Wear Test Machine
   - Carbon disc on rotor
   - 100 hour dry running test (room temp.)
   - Evaluates torque, disc temperature, & wear
2. Dynamic Test Rig
   - Simulates generic gas turbine “Take-Off” condition.
   - Utilizes aviation carbon circumferential seal
   - Baseline & LST Runners

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Surface Finish Definitions

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- Baseline
  - Uses typical runner with “off-the-shelf” surface finish
    - » 8 RMS finish, runout .001”
- LST
  - Same as Baseline
  - Plus LST process
- LST with improved surface finish
  - Improves the “off-the-shelf” finish
    - » 4 RMS finish, circularity .0005”, runout .001”
    - » Included post LST process

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Wear Test Rig

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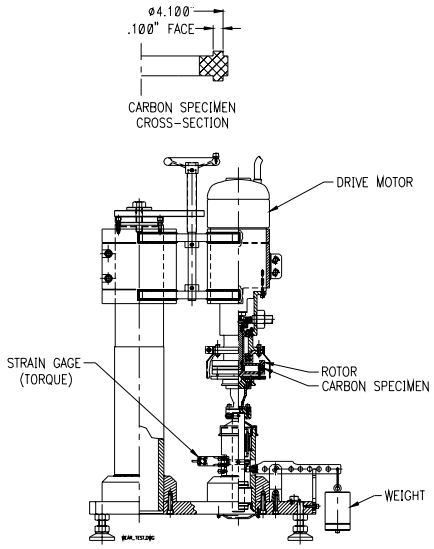

FEATURES:

- Bench top tester
- Permits quick rotor change-outs.
  - Two rotors coatings used:
    - » Tungsten Carbide
    - » Chrome Carbide
  - Baseline & LST rotors

CONDITIONS:

- 100 hour test at room temperature
- 210 ft/sec rotor speed
- 2 psi unit load
- Dry running

DATA ACQUIRED:

- Temperature (Stator)
- Torque
- Coefficient of friction
- Carbon wear rate

Stepped face seal gas bearing static test rig. The seal hardware is a sub-scale version of the actual development seal.

The rig is used to collect information such as:

leakage vs. pressure

clearance vs. pressure

Proximity probes measure the gas film clearance. Effects of taper across the seal and/or rotor can also be tested.

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Wear Test Results (100 hour test)

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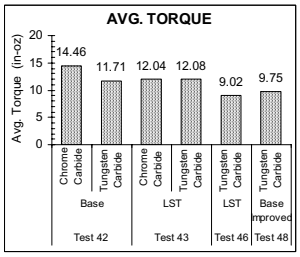

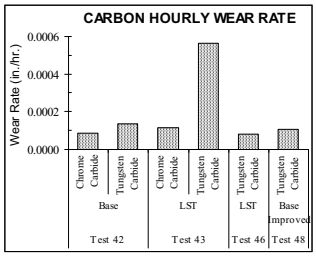

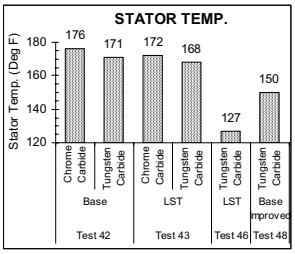

14097 weartest.xls

SUMMARY RESULTS

- Rotors: Baseline, LST, LST with improved finish, and Baseline with improved finish.
- High wear resulted during one test (Test #43, tungsten carbide)
  - Temperature and torque values comparable to other tests.
  - Cause for high wear: Rotor surface roughness exceeded micro-pore's depth
- Test #46 utilized LST rotor with "improved surface finish".
- Test # 48 utilized Baseline rotor with "improved surface finish" (data after 16 hours)

- **Conclusion:** Performance is enhanced with "improved surface finishes"

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Dynamic Test Rig

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CONDITIONS

Air temp.: 400 F

Pressure: 40 psid

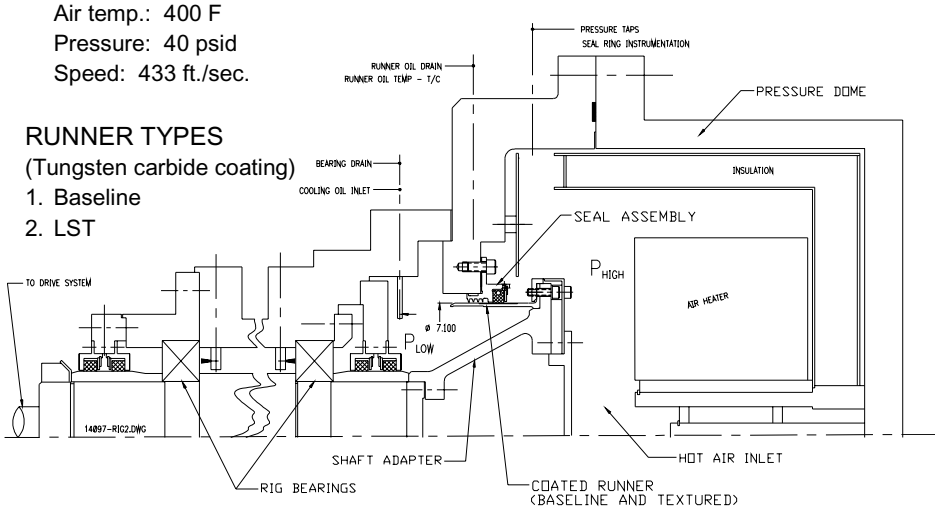
Speed: 433 ft./sec.

RUNNER TYPES

(Tungsten carbide coating)

1. Baseline
2. LST

7.1" O SEAL



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Seal Cross Section - Rig Test

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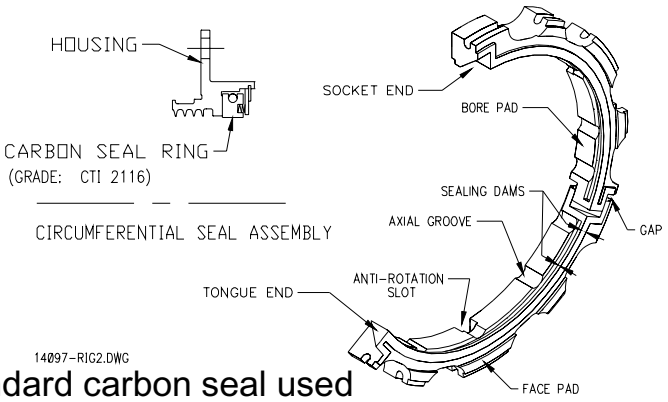

- Standard carbon seal used
  - Carbon graphite grade: USG-2116
- T/C's installed in two segments

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Typical Test Results
Baseline vs. LST Runner

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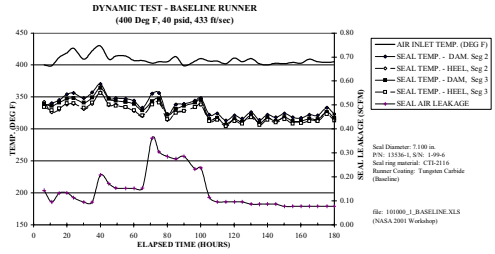

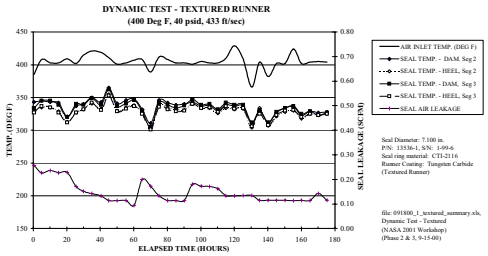

- Typical performance graph for rig tests
  - Elapsed time vs.:
    - » Seal Ring Temp. &
    - » Seal Leakage
  - Inlet air temp: 400 F
- Seal leakage tends to reduce with time as seal wear occurs.
  - Seal ring wears to the distorted runner shape due to thermally and centrifugal effects.

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Dynamic Test Results
Seal Wear & Estimated Life

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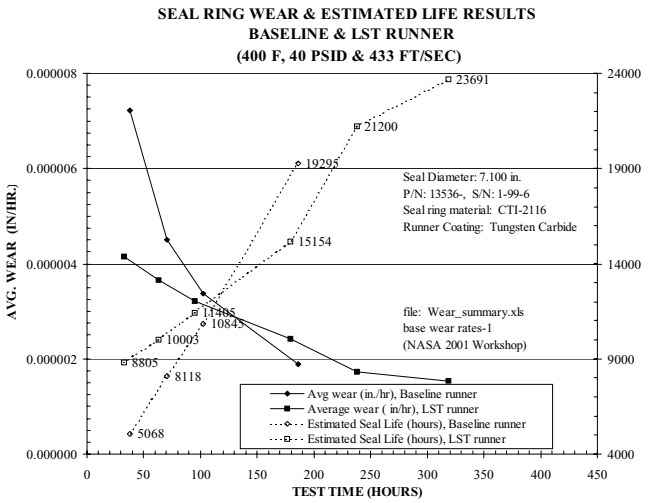

- Compares LST & Baseline runners.
- Seal wear measured at time intervals shown with graph symbol.
- Seal life based on seal ring worn to non-usable condition.
- Baseline runner yielded longer seal life.

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Runner Improvement Implemented

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- Runner surface finish improved
  - Cylindricity
  - Surface Finish
  - Roundness
- LST re-applied with post process operations
  - Smooth “bulges” at pore periphery
  - Lap runner OD

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Dynamic Test Results
LST with Improved Runner Finish

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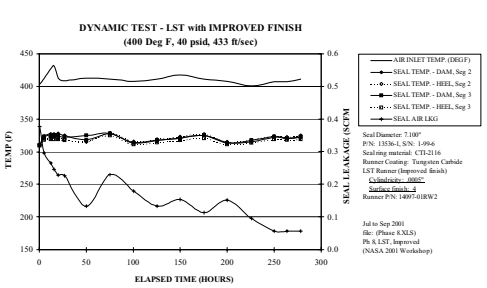

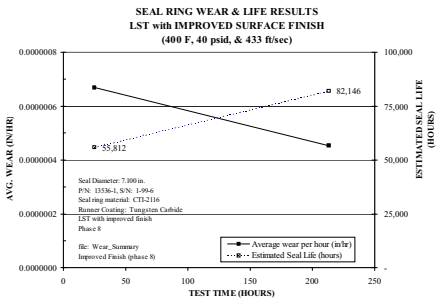

- Seal ring temperature is approx. 18 °F cooler with LST & improved finish
- Seal life measured at two time intervals
  - (25 hr & 278 hr)
- Seal life increased significantly (4.3:1) with LST & improved finish
  - Compared to Baseline Runner.

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Seal Ring Temperature & Wear Life Comparison

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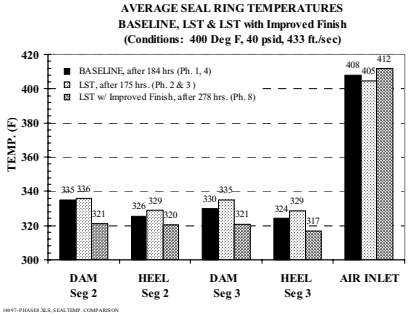

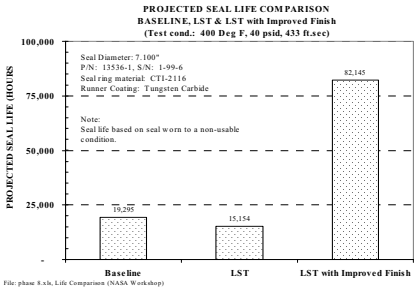

- Seal ring temps. were generally cooler (~ 18 F) with LST and the improved surface finish.``
- Seal life increased 4.3:1 with LST & Improved Surface Finish